CLAIMS

We claim:

1. A sorption pump comprising:

an adsorption layer comprising an adsorption mesochannel containing adsorption media; and

a heat exchanger in thermal contact with the adsorption layer;

wherein the heat exchanger comprises at least one microchannel; and

wherein the adsorption layer has a gas inlet such that gas directly contacts the adsorption media without first passing through a contactor.

2. The sorption pump of claim 1 comprising:

at least 2 adsorption mesochannels, each containing adsorption media, interleaved with at least 3 heat exchanger layers, each heat exchanger layer comprising at least one microchannel.

3. The sorption pump of claim 1 wherein the adsorption layer comprises a plastic and wherein the heat exchanger layer comprises a metal.

4. The sorption pump of claim 1 further comprising a gas outlet separate from the inlet;

wherein the outlet is disposed such that a gas stream can flow through the inlet, through the adsorption media and out the outlet.

5. The sorption pump of claim 4 wherein the pump possesses capability such that, if the adsorption media is replaced with an equal volume of 13x zeolite, with a bulk density of 0.67 grams per cubic centimeter, and then saturated with carbon dioxide at 760 mm Hg and 5 °C and then heated to no more than 90 °C at 760 mm Hg, then at least 0.015 g CO_2 per mL of apparatus is desorbed within 1 minute of the onset of heating.

6. Gas adsorption and desorption apparatus comprising:

at least one adsorption layer comprising an adsorption mesochannel containing adsorption media; and

at least one heat exchanger in thermal contact with the adsorption layer;

wherein the adsorption mesochannel has dimensions of length, width and height;

wherein the height is at least 1.2 mm; and

wherein the apparatus possesses capability such that, if the adsorption media is replaced with an equal volume of 13x zeolite, with a bulk density of 0.67 grams per cubic centimeter, and then saturated with carbon dioxide at 760 mm Hg and 5 °C and then heated to no more than 90 °C, at 760 mm Hg, then at least 0.015 g CO_2 per mL of apparatus is desorbed within 1 minute of the onset of heating.

7 The apparatus of claim 6 comprising:

at least 2 adsorption mesochannels, each containing adsorption media, interleaved with at least 3 heat exchanger layers, each heat exchanger layer comprising at least one microchannel.

8 A method of gas adsorption and desorption, comprising:

passing a gas into an adsorption layer where at least a portion of the gas is adsorbed onto adsorption media to form an adsorbed gas and removing heat from the adsorption layer through a distance of 2 mm or less into a heat exchanger layer;

wherein the gas directly contacts the adsorption media without first passing through a contactor material;

wherein said distance is measured from the center line of the adsorption layer to the center line of the heat exchanger layer;

subsequently, heating the adsorption media through a distance of 2 mm or less from a heat exchanger, and desorbing gas,;

wherein said distance is measured from the center line of the adsorption layer to the center line of the heat exchanger layer.

9. The method of claim 8 wherein heat is exchanged between adsorbent channels and heat exchange channels, within an adsorption cell, at a heat transfer power density that is at least 0.5 watts per cubic centimeter.

10. The method of claim 8 comprising selectively heating and selectively cooling the adsorption layer.

11. A method of gas adsorption and desorption, comprising:

a first step of passing a gas into an first adsorption layer containing a first adsorption media where at least a portion of the gas is adsorbed onto the adsorption media and exchanging heat with the adsorption layer through a distance of 1 cm or less into a first heat exchanger;

wherein said distance is measured from the center line of the adsorption layer to the center line of the heat exchanger;

subsequently, in a second step, the adsorption media exchanges heat through a distance of 1 cm or less from the first heat exchanger, and gas is desorbed;

wherein said distance is measured from the center line of the adsorption layer to the center line of the heat exchanger;

simultaneous with the first step, a heat exchange fluid flows through the heat exchanger and exchanges heat with the adsorption layer, and the heat exchange fluid then flows into a second heat exchanger which exchanges heat with a second adsorption layer and cools a second adsorption layer containing a second adsorption media.

12. A method of gas adsorption and desorption, comprising:

passing a gas into an adsorption layer where at least a portion of the gas is adsorbed onto adsorption media to form an adsorbed gas and selectively removing heat from the adsorption layer through a distance of 1 cm or less into a heat exchanger;

subsequently, selectively heating the adsorption media through a distance of 1 cm or less from a heat exchanger, and desorbing gas.

13. The method of claim 12 wherein the adsorption layer has a serpentine configuration.

14. The method of claim 12 wherein the structural material of the adsorption layer is composed of plastic.

15. The method of claim 12 wherein the gas directly contacts the adsorption media without passing through a contactor material.

16. The method of claim 15 wherein the adsorption media occupies at least 80% of the cross-section of the adsorption channel such that essentially all of the gas passing into the adsorption channel contacts the adsorption media.

17. The method of claim 15 wherein fluid-containing channels of the heat exchanger overlap at least 90% of the adsorption channel.

18. Gas adsorption and desorption apparatus comprising:

at least 4 adsorption/desorption cells

each cell comprising at least one adsorption mesochannel in thermal contact with at least one heat exchanger;

wherein the adsorption channel contains adsorption media;

the apparatus connected to a heat source and a heat sink; and

conduits between each heat exchanger and the heat source and the heat sink and also conduits between at least one heat exchanger in each cell and at least one heat exchanger in another cell.

19. The apparatus of claim 18 wherein the at least one heat exchanger comprises a microchannel heat exchanger.

20. A sorption pump, comprising:

an adsorption layer comprising an adsorption channel containing adsorption media; and

a mesochannel heat exchanger in thermal contact with the adsorption layer;

wherein the mesochannel heat exchanger has a fluid flowing therethrough that has a high thermal diffusivity, such that the characteristic heat transport time of the fluid in combination with the mesochannel heat exchanger is a value no greater than 10 seconds.

21. The sorption pump of claim 20 wherein said fluid is a liquid metal or a silicone-based fluid.

22. A multi-cell sorption pump, comprising:

at least six sorption cells; wherein each sorption cell comprises at least one adsorption layer, and at least one heat exchanger layer;

thermal connections connecting each sorption cell to at least two other sorption cells and to a heat source and to a heat sink, such that each sorption cell can cycle thermally from adsorption to desorption and back to adsorption by sequentially receiving heat from said at least two other sorption cells prior to receiving heat from the heat source, and then sequentially giving up heat to at least two other sorption cells prior to giving up heat to the heat sink, such that thermal recuperation is provided.

23. The method of claim 11 wherein themal swing adsorption is attained.

24. The multi-cell sorption pump of claim 22, wherein the heat source is selected from the group consisting of an electrical resistor, a process technology, solar power, nuclear power.

25. The multi-cell sorption pump of claim 22, where the thermal connections are heat switches.

26. The multi-cell sorption pump of claim 22, wherein the thermal connections comprise fluid loops.

27. The multi-cell sorption pump of claim 22, wherein the sorption pump incorporates mesochannel sorption channels, and wherein the sorption pump incorporates mesochannel heat exchange channels.

28. A method of adsorbing and desorbing a gas, comprising:

a first step of transferring heat from a heat source into at least two first cells; and

desorbing gas from each of said two first cells;

transferring heat from at least two second cells to at least two third cells;

a second step of transferring heat from said at least two second cells to a heat sink; and

adsorbing gas into said at least two second cells;

transferring heat from said at least two first cells to said at least two third cells;

a third step of transferring heat from a heat source into the said at least two third cells; and

desorbing gas from each of said at least two third cells;

transferring heat from said at least two first cells to said at least two second cells;

a fourth step of transferring heat from said at least two first cells to a heat sink; and

adsorbing gas into said at least two first cells;

transferring heat from said at least two third cells to said at least two second cells;

wherein each cell comprises at least one sorbent, and at least one heat exchanger.

29. The method of claim 28 wherein thermochemical compression is attained.

30. The method of claim 28 wherein each cell comprises at least one microchannel heat exchanger.

31. The sorption pump of claim 5 where the adsorption media is heated to 90°C by flowing warm water at 90°C through the heat exchange channels.

32. The method of claim 8 wherein heat is exchanged between adsorbent channels and heat exchange channels, within an adsorption cell, at a heat transfer power density that is at least 1.0 watts per cubic centimeter.

33. The method of claim 11 wherein thermally-enhanced pressure swing adsorption is attained.

34. The method of claim 11 wherein thermochemical compression is attained.

35. The method of claim 28 further comprising:

a fifth step comprising transferring heat from a heat source into the said at least two second cells; and desorbing gas from each of said at least two second cells, and transferring heat from said at least two third cells to said at least two first cells; and

a sixth step comprising transferring heat from said at least two third cells to a heat sink; and adsorbing gas into said at least two third cells; and transferring heat from said at least two second cells to said at least two first cells; thereby attaining thermal recuperation.